Public Roads

www.fhwa.dot.gov
November/December 2012

The Rise of Electric Cars

Mini-Roundabouts

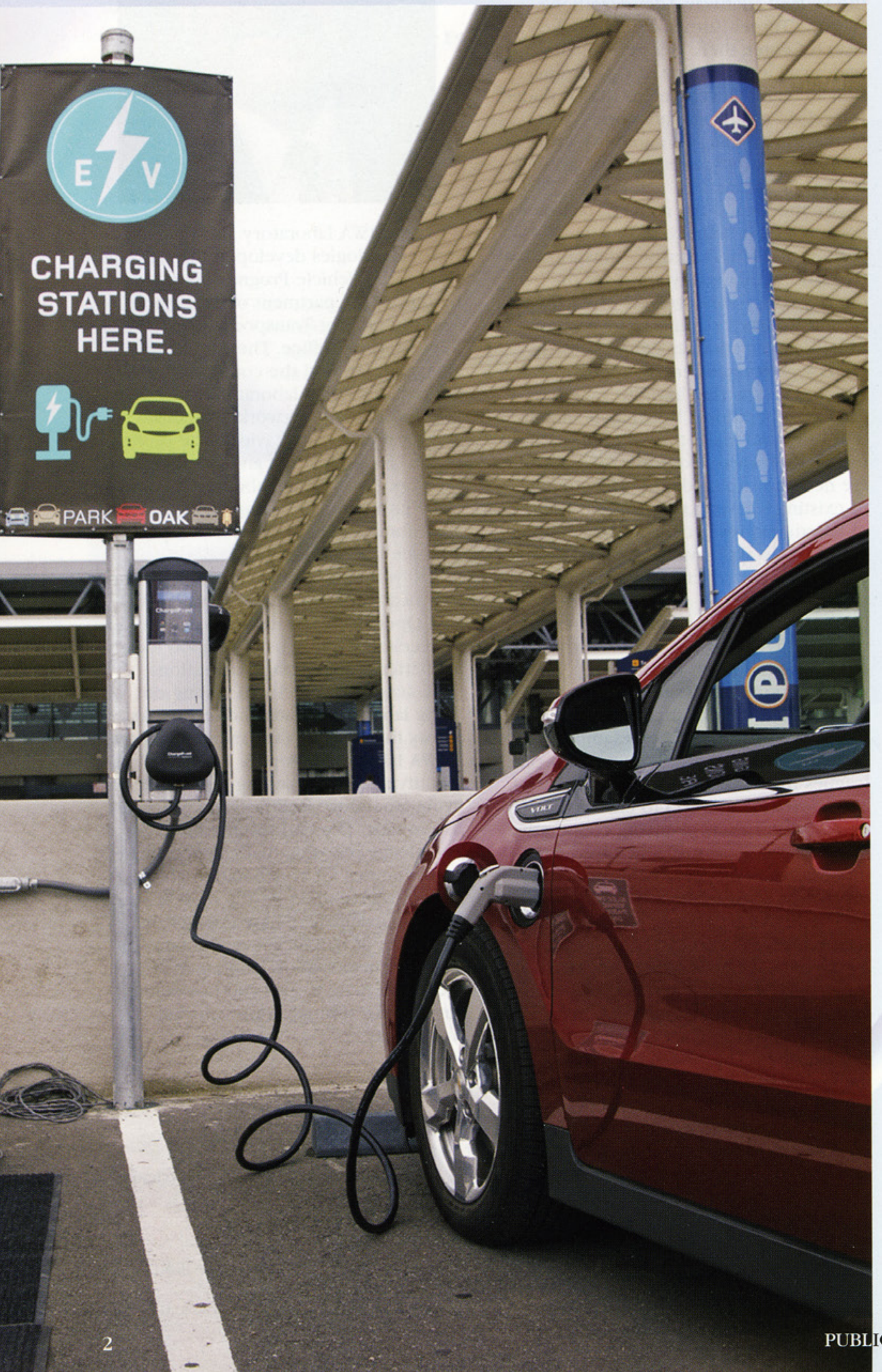
Solar in the Right-of-Way

U.S. Department of Transportation
Federal Highway Administration

The Car of the Future, *Today*

by Diane Turchetta

Plug-in electric vehicles have the potential to be a cleaner, more sustainable option for personal travel than conventional vehicles. But market penetration will take time.



The traditional fossil fuels used to power the Nation's fleet of automobiles come with significant economic, national security, and environmental costs. For example, almost half of the total U.S. trade deficit in 2010—$265 billion of $646 billion—was oil related. In addition, as the world's largest oil importer, the United States is economically vulnerable to supply disruptions, resulting in the need for military operations to ensure that foreign oil fields and overseas shipping lanes remain open and secure. Further still, concerns persist about the impacts of the emissions from the burning of these fuels on air quality and climate change.

For these reasons and more, manufacturers and the traveling public are increasingly investing in plug-in electric vehicle (PEV) technologies. Electric vehicles include

(Left) USDOT is funding research and development related to plug-in electric vehicles (PEVs), such as this one recharging at a station that is part of the ChargePoint network, a public-private partnership between DOE and Coulomb Technologies, Inc.
Photo: Coulomb Technologies, Inc.

pure battery electric vehicles, plug-in hybrid electric vehicles, hybrid electric vehicles, and extended-range electric vehicles. The increased adoption of this vehicle technology promises to yield multiple benefits, including reducing U.S. reliance on foreign sources of oil, lowering localized and regional onroad emissions, and potentially decreasing greenhouse gas emissions, depending on the source of fuel the electrical grid is using. Many States and localities in the United States are beginning to build the necessary infrastructure to support regular use of PEVs.

The Obama administration set a goal of getting 1 million advanced technology vehicles, such as PEVs, on the road by 2015. The administration also developed new initiatives to support advanced technology vehicles. For example, tax incentives have proven effective in providing the additional boost needed to encourage mainstream consumers to choose PEVs over conventional fuel vehicles. The American Recovery and Reinvestment Act of 2009 (Recovery Act) established tax credits for purchasing electric vehicles ($2,500–$7,500 per vehicle, depending on the battery capacity) and conversion kits to retrofit conventionally powered vehicles with electric vehicle capability ($4,000 per vehicle maximum). In addition, nearly all States and the District of Columbia have adopted other measures promoting electric-drive vehicle usage, including high-occupancy vehicle privileges and waived emissions inspections, as well as tax credits or rebates and preferred purchase programs.

Over the next few years, nearly all major automakers plan to put PEVs on the road. The U.S. Department of Energy (DOE) estimates PEV production levels to be more than 1.2 million total through 2015. However, actual production and market penetration depend on many variables, including improvements in PEV battery technology, vehicle cost, the price of conventional fuels, and consumer behavior. What follows is a closer look at these challenges and what is being done at the Federal and State levels to overcome them.

Types of Electric Vehicles

- **Battery electric vehicles**, such as the Nissan LEAF®, are powered by an electric motor and run on batteries charged by electricity, similar to cell phones or digital cameras. Because battery electric vehicles run purely on electric charges, they emit no tailpipe emissions.
- **Plug-in hybrid electric vehicles** have both an electric battery and a gasoline or other hydrocarbon-fueled engine. These vehicles run on an electric charge but switch to other fuels when the battery runs down.
- **Hybrid electric vehicles** combine the engine of a gasoline or other hydrocarbon-fueled vehicle with the battery and electric motor of an electric vehicle. The combined engine allows hybrid electric vehicles to achieve better fuel economy than traditional vehicles. Hybrid electric vehicles do not need to be plugged in; the battery is charged by the internal combustion engine or other propulsion source and during regenerative braking.
- **Extended-range electric vehicles**, such as the Chevrolet Volt, have an electric motor. The owner can plug in while stationary to charge the battery; while traveling, an onboard generator, such as a gasoline-, diesel-, or ethanol-fueled engine, kicks in to further power the electric motor.

Challenges to Mass Integration

A number of barriers stand in the way of broader consumer acceptance and more widespread deployment of electric vehicles. One major obstacle to the growth of the PEV market is the higher upfront vehicle cost compared to conventional automobiles. The high cost of the battery system for battery electric vehicles and the advanced drivetrain system for plug-in hybrid electric vehicles accounts for much of the additional cost. For example, the manufacturer's suggested retail price for the Chevrolet Volt is $39,145 and for the Nissan LEAF® is between $35,200 and $37,250, depending on the model. Even with Federal tax incentives, the cost of PEVs remains well above the cost of most comparably sized conventional automobiles, many of which retail in the range of $15,000 to $25,000.

For many consumers, the limited range of PEVs, especially battery electric vehicles, is also a barrier to purchasing. According to Nissan,

AeroVironment, Inc.

Shown here is a residential charging station, the most common way today's PEV owners charge their vehicles.

Types of Charging

- **Level 1:** This level of service is provided by a typical household outlet and is most appropriate for PEVs with relatively small battery packs, low daily mileage, or limited access to Level 2 charging.
- **Level 2:** This level of service is appropriate to fully charge most PEVs overnight. Compared to Level 1 charging, it can cut the charge time in half. Level 2 charging may require homeowners to upgrade their electrical panel to provide a dedicated circuit for PEV charging. The same connector is used for Level 1 and 2 charging, and most new PEVs are compatible with both voltage levels.
- **DC Fast Charging:** DC charging is often referred to as "fast charging." This level of charging can accommodate high-traffic commercial locations, such as fleet installations, gas stations, and charging stations along major transportation corridors.
- **Battery Switching:** An automated process exchanges a depleted battery with a fully charged one.

the LEAF®'s expected all-electric range with a fully charged battery is more than 135 miles (217 kilometers) in ideal conditions, and the U.S. Environmental Protection Agency (EPA) lists the car's official range as 73 miles (117 kilometers) based on tests using varied driving conditions and climate controls. Consumers looking for a farther range may opt for plug-in hybrid electric vehicles, which switch to running fully on gasoline when the battery runs down.

Most of the PEVs currently on the market use lithium-ion batteries, widely known for their use in laptops and consumer electronics. However, work is currently underway to develop and test new battery chemistries. Under the Recovery Act, DOE is funding battery and electric drive component manufacturing, as well as research and development, so battery manufacturers can benefit from economies of scale to lower costs and develop new battery chemistries with higher energy densities. If successful, the new technologies could help reduce consumer concerns about driving range and vehicle price.

Another challenge to integrating PEVs into the mainstream is the availability of charging infrastructure. At least in the early stages of adoption, most PEV owners will charge their vehicles in their homes overnight. To do so, owners must have a Level 2 charger installed to fully charge a battery electric vehicle and at least a Level 1 charger for plug-in hybrid and extended-range electric vehicles. A Level 1 charger provides 2–5 miles of range per hour of charging, typically using a 120-volt outlet, and a Level 2 charger provides 10–20 miles of range per hour of charging using a 240-volt outlet.

Nonresidential charging infrastructure also is important for developing PEV markets. To maximize the full range of PEVs, consumers not only need a home charger but also will want to charge their cars while on the go. Charging stations could be installed on commercial properties such as places of employment, grocery stores, public parking lots, and airports; curbside at both commercial and residential locations such as apartment and condo buildings; and at stopping points along highways such as rest areas. In addition, each location would require an appropriate charging level to meet the needs of the various types of electric vehicles. Moving Ahead for Progress in the 21st Century (MAP-21), the most recent surface transportation bill passed in July 2012, permits transportation funding to be used to fund electric vehicle charging infrastructure at "fringe and corridor parking facilities."

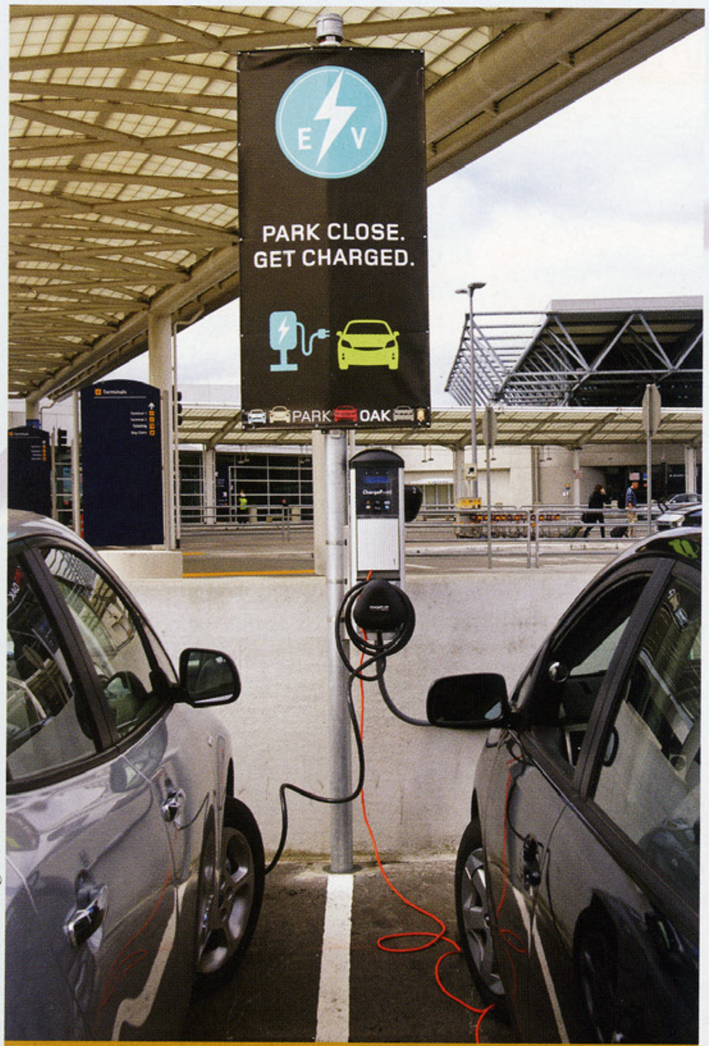
Strategic placement is another issue related to nonresidential charging infrastructure. Placement may be influenced by land-use patterns, geography, and level of traffic congestion. Both the public and the private sectors have invested in charging infrastructure; however, public-private partnerships are the most popular method of deploying charging infrastructure to date. The two largest pilot projects are public-private partnerships between DOE and two private companies, ECOtality, Inc., and Coulomb Technologies, Inc. DOE also provided a nearly $1 million Electric Vehicle Readiness Grant to the New York State Energy Research & Development Authority on behalf of the Transportation and Climate Initiative. The grant supports the Northeast Electric Vehicle Network, a group of 11 Northeast States including the District of Columbia. Another example is the U.S. Department of Transportation's (USDOT) award of $3.34 million in TIGER (Transportation Investment Generating Economic Recovery) II grant funding to extend the initial network of direct current (DC) fast-charging stations in rural northwestern Oregon along key corridors such as routes to the coast and mountains, strategically linking travel destinations throughout the northwestern part of the State. The goals of these projects are to promote the deployment of infrastructure to support PEVs and to evaluate how that infrastructure is used.

An alternative to public fast-charging stations is battery switch

Charging Options

	Current Type	Amperage	Voltage	Kilowatts	Charging Time	Primary Use
Level 1	Alternating current	12–16	120	1.3–1.9	2–5 miles of range per hour of charging	Residential charging
Level 2	Alternating current	Up to 80	240	Up to 19.2	10–20 miles of range per hour of charging	Residential and public charging
DC Fast Charging	Direct current	Up to 200	208–600	50 to 150	60–80 miles of range in less than 30 minutes	Public charging

Source: DOE, Energy Efficiency and Renewable Energy, Vehicle Technologies Program, May 2011.



Coulomb Technologies, Inc.

(Above) Two PEVs are recharging at a ChargePoint station at the Oakland International Airport in Oakland, CA.

stations, where a driver enters a lane and then a robotic system in the station takes over the process of switching out a depleted battery for a charged one. The car proceeds along a conveyor while the automated switch platform below the vehicle aligns under the battery, washes the underbody, initiates the battery release process, and lowers the drained battery from the vehicle. The depleted battery is then placed onto a storage rack for charging, monitoring, and preparation for use in another vehicle. A fully charged battery is lifted into the waiting car. The switch process takes less time than a stop at the gas station, and the driver and passengers may remain in the car throughout. The private sector is leading the charge to develop this battery-leasing business model and infrastructure, and introduce it to the United States in California.

Managing energy demand between PEV charging and the existing demand on the electrical grid is yet another challenge. The impacts of charging will vary by region, depending on PEV market penetration, the types of PEVs adopted, the method of electricity generation, and seasonal variations in electricity use. One potential solution is charging reduced electricity rates during offpeak hours, typically at night when most residential charging occurs. However, as PEV use increases and the need for charging during peak hours becomes a necessity, it could put stress on the grid and potentially cause disruptions in electric service.

Another potential solution is deployment of "smart grid" technology to ease the demand. Smart grid technology enables the grid to collect information about the electricity use patterns of suppliers and consumers to improve the efficiency and reliability of the grid, and provide more efficient transmission of electricity to the consumer, including quicker restoration of electricity after power disturbances.

Finally, perhaps the most crucial issue surrounding the success of PEV deployment is consumer acceptance. In order for manufacturers to meet PEV production goals by 2015, PEVs must generate a healthy demand among consumers. Demand could increase quickly if the price becomes more competitive with conventional automobiles, if vehicle tax incentives increase, or if gas prices rise significantly. Also, all levels of government, public utilities, automakers and dealers, and other private sector entities must address the need for public outreach and education on PEV issues, including PEV technology, driving ranges,

(Below) This PEV owner plugs in his vehicle at a Blink charging station in Wilsonville, OR.

ECOtality, Inc.

Expected PEV Production Levels Through 2015*

Make and Model	Type	2011–2015
Fisker Karma	Plug-in Hybrid Electric Vehicle	36,000
Fisker Nina	Plug-in Hybrid Electric Vehicle	195,000
Ford Focus	Battery Electric Vehicle	70,000
Ford Transit Connect	Battery Electric Vehicle	4,200
Chevrolet Volt	Plug-in Hybrid Electric Vehicle	505,000
Navistar eStar™ (truck)	Battery Electric Vehicle	4,000
Nissan LEAF®	Battery Electric Vehicle	300,000
Smith Electric Vehicles Newton™ (truck)	Battery Electric Vehicle	5,000
Tesla Motors Model S	Battery Electric Vehicle	55,000
Tesla Motors Roadster	Battery Electric Vehicle	1,000
THINK City	Battery Electric Vehicle	57,000
Total		**1,232,200**

**Note: This chart was developed before announcements that Chevrolet would idle production of the Volt in March and August 2012.*
Source: DOE, One Million Electric Vehicles by 2015: February 2011 Status Report, *2011.*

charging infrastructure, and safety. In the end, the consumer will determine whether the adoption of PEVs accelerates or stalls.

Other Issues

Additional issues from a transportation and highway perspective include: (1) concerns over life-cycle greenhouse gas emissions associated with the operation of PEVs, (2) impacts of reduced gas tax revenues on the Highway Trust Fund, and (3) the current prohibitions on commercialization of interstate rights-of-way as described in Title 23 of the U.S. Code of Federal Regulations.

Life-cycle greenhouse gas emissions account for emissions from an activity or source from "cradle to grave." This may include estimating emissions upstream of the traditional point of measurement—taking into account the raw materials used in making a product or the energy used to transport the product to a local market, for example—as well as estimating downstream emissions resulting from consumption and disposal. From an environmental perspective, it is important to ensure that PEV adoption does not result in the transfer of emissions from one sector (transportation) to another (electricity). PEVs produce no tailpipe emissions. However, from a life-cycle point of view, the electricity used to charge these vehicles could be associated with greenhouse gas emissions if generated by the burning of coal or other fossil fuels. Electricity generated from renewable energy sources, such as hydropower, solar, wind, biomass, or geothermal, results in significantly lower greenhouse gas emissions than that generated by coal-fired plants.

The impact of PEVs on transportation funding also remains to be addressed. Currently, Federal and State fuel taxes on gasoline and diesel provide a significant contribution to funding for maintaining roadways. Because electric vehicles do not use conventional fuel (that is, gasoline or diesel), they pay no fuel tax, which means they do not contribute to the Highway Trust Fund. While this is less a problem in the early stages of adoption, losses due to the use of electricity as a transportation fuel will comprise about 1 percent of projected revenue shortfalls through 2015. Some States, such as Washington, are currently considering legislation that will tax PEV owners based on the amount of electric miles driven. In March 2012, Washington State enacted legislation that imposes a $100 annual fee on electric vehicles, the proceeds of which must be used for highway maintenance and preservation. Separate legislation funded a feasibility study of a road user charge system, which may be tested first on electric vehicles to account for miles driven.

Another potential source of revenue for State departments of transportation (DOTs) from the installation of renewable energy technologies and alternative fuel facilities, including PEV charging, on the highway right-of-way is the sale of carbon offsets or renewable energy

This Blink charging station, part of a public-private partnership between DOE and ECOtality, Inc., is solar powered.

ECOtality, Inc.

WSDOT

In Skykomish, WA, several electric vehicles stop to charge up at this public charging station along Stevens Pass Greenway Scenic Byway.

credits. A carbon offset is a reduction in greenhouse gas emissions made in order to compensate for or offset emissions made elsewhere. A renewable energy credit represents the environmental attributes of the power produced when a renewable energy facility opens (one renewable energy credit is equivalent to 1 megawatt-hour of electricity generated). However, Section 111 of Title 23, United States Code, currently prohibits commercialization of interstate rights-of-way, including any activity that is fee based. Therefore, charging the public a fee for the electricity used to charge PEVs is prohibited. Removing this provision, or providing an exemption for charging infrastructure, could provide States with an opportunity to accelerate the transition to cleaner burning vehicles and potentially create a revenue source for highway construction and maintenance activities.

FHWA Research And Initiatives

Recognizing the important role that PEVs likely will play in the future, and the potential impacts they will have on the Nation's transportation system, the Federal Highway Administration's (FHWA) Office of Planning, Environment, and Realty has initiated several projects to help accelerate the deployment of PEVs and charging infrastructure. The office is also analyzing how the penetration of PEVs into the current fleet may impact FHWA's mission.

"FHWA is committed to assisting State DOTs with determining what is necessary in establishing an infrastructure that supports and maximizes the benefits of electric vehicle deployment, including reducing energy consumption and improving the sustainability of the transportation system," says Gloria Shepherd, associate administrator of FHWA's Office of Planning, Environment, and Realty.

FHWA partnered with the American Association of State Highway and Transportation Officials (AASHTO), the Center for Climate and Energy Solutions, and numerous other stakeholders to develop *An Action Plan to Integrate Plug-In Electric Vehicles with the U.S. Electrical Grid*. The plan provides a comprehensive strategy for public and private actions to build infrastructure and

I–5 by the Numbers

1,350	Miles (2,173 kilometers) from Canada to Mexico
550	Miles (885 kilometers) pass through heavily congested urban areas
71,000–300,000	Number of vehicles on the corridor daily
10,000–35,000	Number of commercial trucks daily
150,000	Projected number of vehicles daily by 2035 without further improvement to the corridor
95%	Portion of corridor projected to be heavily congested by 2035 without major intervention

Source: USDOT.

educate consumers, with the goal of accelerating PEV adoption.

In January 2012, FHWA and RITA's John A. Volpe National Transportation Systems Center completed a report that investigates the implications of accommodating renewable energy technologies and alternative fuel facilities within highway right-of-way. The report, *Alternative Uses of Highway Right-of-Way*, offers a snapshot of issues in a rapidly evolving field and provides transportation agencies with information that could help them in pursuing future renewable energy projects.

FHWA has recently initiated a research project, titled Feasibility and Implications of Electric Vehicle Deployment and Infrastructure Development, which focuses on the prospects and expectations for short- and long-term deployment of electric vehicles. The study will analyze the potential impact of this deployment on FHWA's mission, the financial implications for available highway revenues, and potential infrastructure development needs. The results of the research will assist State and local transportation agencies in understanding whether and how transportation infrastructure might have to change to facilitate, support, and provide emergency response to electric vehicles.

WSDOT Secretary of Transportation Paula Hammond speaks at a grand opening event for the West Coast Electric Highway in Bellingham, WA, on May 30, 2012.

WSDOT

FHWA also is working to organize a summit to investigate the use of rights-of-way to grow biofuel feedstock crops. The goal would be to increase the production of biofuels without affecting food, fiber, feed, or flower production by using available lands along highway roadsides, at military bases, and at airports.

In addition, a new research project is underway, with support from FHWA's Exploratory Advanced Research Program, to study the use of inductive charging technologies for electric vehicles. Inductive charging uses an electromagnetic field from coils embedded in the ground to transfer electricity to the battery pack of a PEV without the need for a cord. This technology could be useful to curb consumer anxiety about charge range since charging can occur while a car is in motion.

West Coast Electric Highway

The Washington State Department of Transportation (WSDOT) is among the States leading the charge to install PEV infrastructure. The department is supporting the West Coast Electric Highway, a network of electric vehicle fast-charging locations along I-5. The public charging stations enable

WSDOT

This WSDOT booth provided information about the West Coast Electric Highway to attendees at one of the grand opening events.

PEV drivers to travel the length of the State, 276 miles (444 kilometers) of I-5 between Washington's borders with Oregon and Canada. The $1.5 million project is funded by DOE with Recovery Act dollars administered by the Washington State Department of Commerce through the State Energy Program.

Through a competitive contract award process, AeroVironment, Inc., was selected to manufacture, supply, install, and operate the network of fast chargers. Stations are located every 20 to 35 miles (32 to 56 kilometers) along stretches of I-5 between the Canadian border and Everett and between Olympia and the Oregon border. Branching out from I-5 onto east-west corridors, charging stations are also in communities along U.S. 2 between Everett and Wenatchee and on I-90 between North Bend and Cle Elum.

The fast-charging stations can power an all-electric vehicle from zero to approximately 80 percent charged in 30 minutes. Each charging location also includes a Level 2 pedestal for other models of PEVs. The stations are conveniently placed at private retail locations such as shopping malls, fueling stations, and travel centers with easy access to the highway.

In addition to the private retail locations, Level 2 charging equipment is available at two of Washington's gateway safety rest areas along I-5 where a combined total of more than 1 million visitors stop each year. Nonprofit organizations Adopt a Charger and the Seattle Electric Vehicle Association cover the electricity costs for charging at these rest areas.

Similar projects managed by the Oregon Department of Transportation expand the charging network, giving Pacific Northwest drivers the ability to travel through Oregon to the California border. Both States' initiatives complement The EV Project, a $230 million public-private partnership project to deploy electric vehicle charging infrastructure in six States including California, Oregon, and Washington.

"A 21st century transportation system in Washington must provide options for drivers, especially as more people convert to electric vehicles," says WSDOT Secretary of Transportation Paula Hammond. "Creating a sustainable transportation system protects our air from harmful emissions and conserves our resources."

The West Coast Green Highway initiative promotes the use of electric vehicles and cleaner fuels along I-5 from Canada to Mexico. *Source: WSDOT.*

The EV Project was developed as part of the West Coast Green Highway initiative to promote the use of cleaner fuels along I-5 from British Columbia to Baja, CA. The initiative supports the development of a regional electric vehicle network spreading across the entire 1,350 miles (2,173 kilometers) of I-5 connecting three States and three countries. Officials expect that the corridor will serve up to 2 million electric vehicles on the west coast by 2020.

The Future of Electric Vehicles

Electric vehicle development (both vehicle and battery technologies) and deployment are in their infancy, as is charging infrastructure. Nevertheless, the future may hold many innovative solutions to charging such as inductive, or wireless, charging or the use of solar energy.

The introduction of new technologies typically presents barriers and hurdles to be overcome. The deployment of PEVs and charging infrastructure is no different. If successful, the penetration of PEVs into the existing vehicle fleet will mean some significant changes for the transportation sector, from both the infrastructure and user perspectives.

"The use of PEVs and the continued research necessary to improve electric vehicle performance are essential to the development of a 21st-century transportation system," says Kevin Womack, associate administrator for the Office of Research, Development, and Technology at RITA. "The application of electric vehicles in any form is critical to the economic competitiveness and environmental well-being of the United States."

Diane Turchetta is a transportation specialist in FHWA's Office of Planning, Environment, and Realty. She works primarily on transportation and climate change issues. Turchetta received a B.S. in public administration from The Pennsylvania State University and a master's in public administration from Virginia Tech.

For more information, contact Diane Turchetta at 202-493-0158 or diane.turchetta@dot.gov.

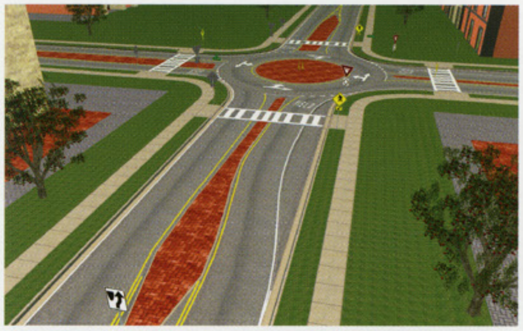
Public Roads

—featuring developments in Federal highway policies, programs, and research and technology—

November/December 2012 www.fhwa.dot.gov Vol. 76, No. 3

Articles

Page 2



Page 14

Page 20

Departments

Front cover—To reduce the country's dependence on fossil fuels, electric vehicles are one option. With more of these automobiles on the road, California, Oregon, and Washington State are supporting the West Coast Electric Highway initiative, which aims to increase the availability of fast-charging infrastructure, such as the station this charger is connected to, along I-5 in Washington State. For more information, see "The Car of the Future, Today" on page 2 in this issue of PUBLIC ROADS. *Photo by Jessie Lin, Washington State Department of Transportation.*

Back cover—Oregon is leading the way in installing renewable energy along highways. This solar array is one of two projects recently completed along I-5 near Portland. The State has the potential to generate 68 million megawatt-hours of solar energy and, through even partial development of those resources, could produce its current annual energy use of 48 million megawatt-hours. For more information, see "Spotlight on Solar Arrays" on page 20 in this issue of PUBLIC ROADS. *Photo by Gary Weber, ODOT Photo/Video Services.*